PARALLAX

- Definition: "the apparent shift or movement of a nearby object against a distant background, when viewed from two different positions"

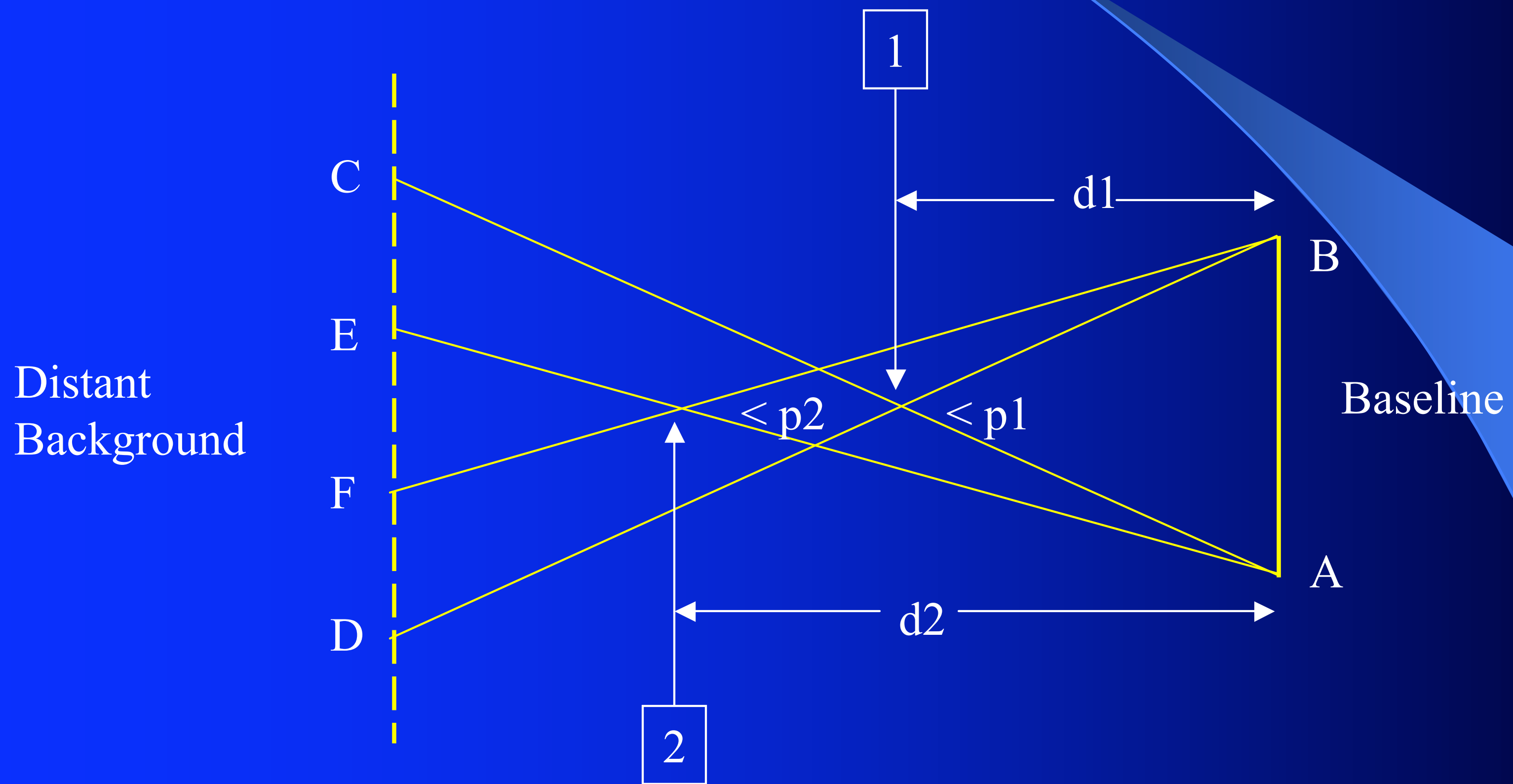
Examples of parallax

- Thumb in front of the eyes
- Speedometer (not digital) viewed by the driver vs. the passenger
- An object in the room when viewed from the RHS of the room vs. the LHS
- A flagpole when viewed from opposite ends of a sidewalk

Vocabulary of parallax

- Baseline
- Parallax shift or parallax angle
- Distance
- Small angle formula
- Arcseconds

Geometry of parallax



Conclusions

- Nearby objects have a greater parallax shift and a larger parallax angle than more distant objects.
- Conversely: If an object A has a larger parallax shift than an object B, using the same baseline, then A is closer than B.
- Extension: A longer baseline will produce a larger parallax shift for the same object.

How to measure d1 or d2?

If the scale were correct in the diagram, we would use "triangulation"

Measure the baseline AB.

Measure the angles at A and B.

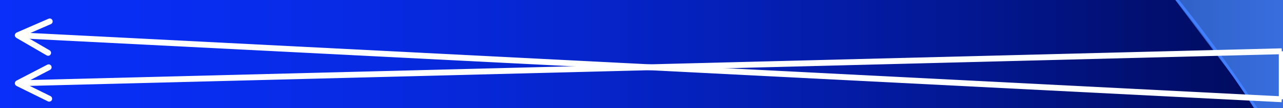
Create a simple scale drawing and measure d.

OR, use simple trigonometry to calculate d.

But…….in astronomy:

- The distances to most objects of interest are extremely large.
- Earth-based baselines make angles at A and B nearly 90 degrees!
- These angles are nearly impossible to measure accurately.

The picture becomes…….

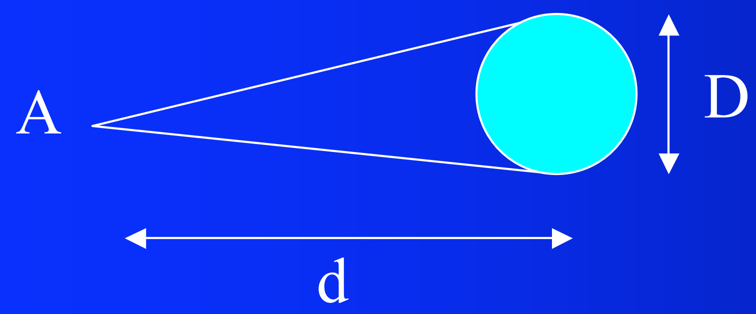


….a very long, thin isosceles triangle.

The issue becomes one of measuring:

VERY TINY ANGLES!!

The Small Angle Formula

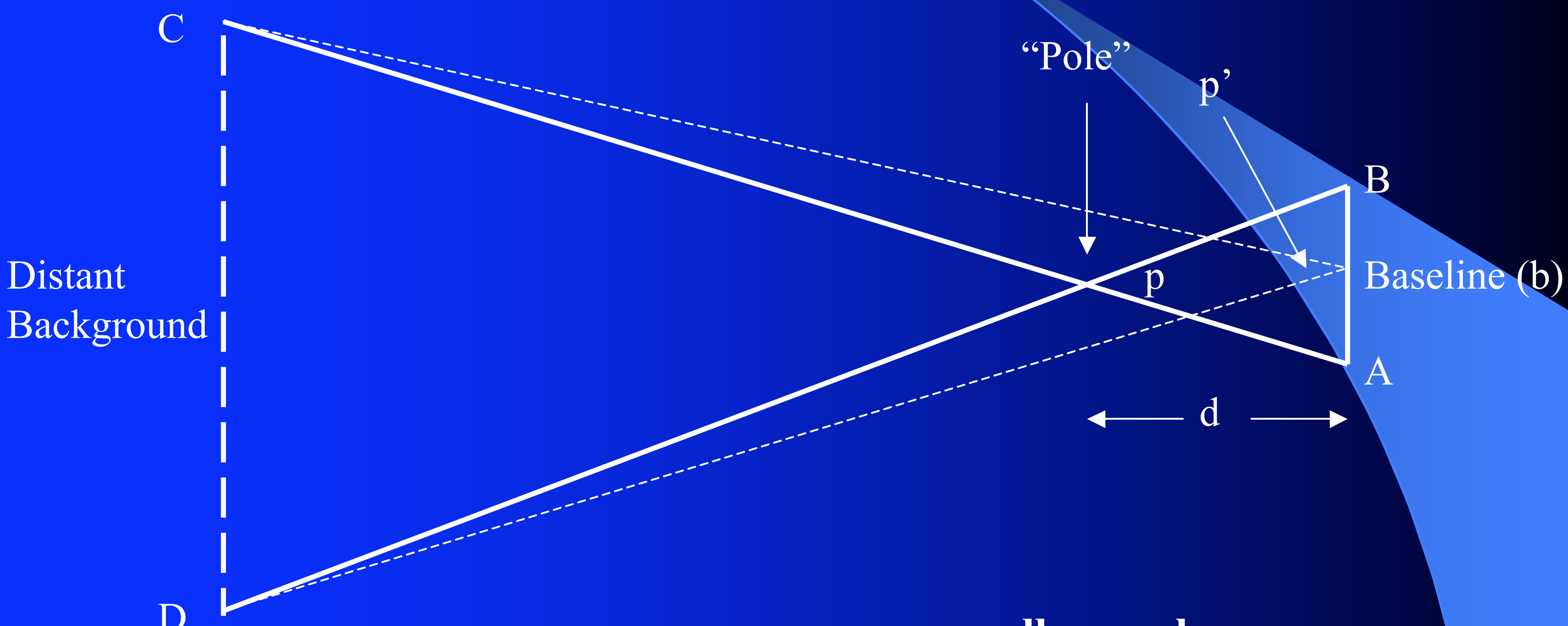


The Small Angle formula becomes:

Angle A = (D/d) x 206,265

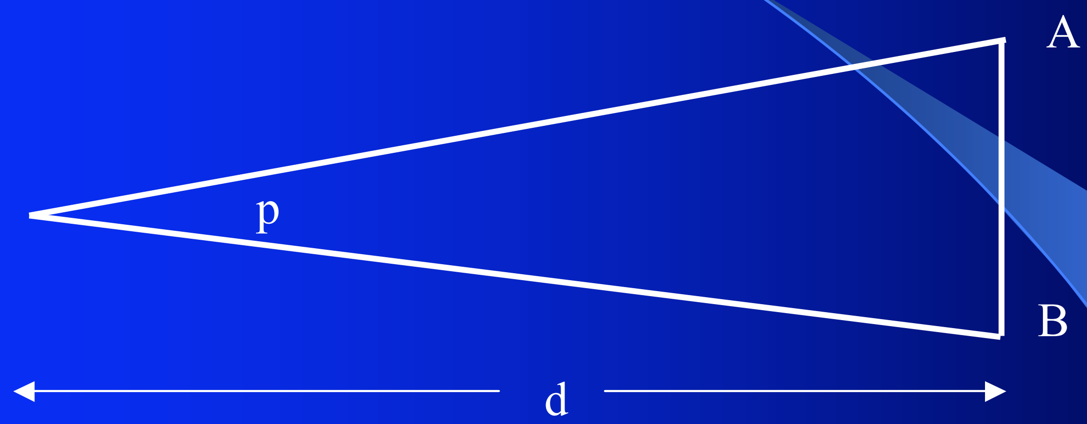
(A in arcseconds)

Outdoor Parallax



p = parallax angle

Basic Geometry



The small angle formula gives us: $p = (AB/d) \times 57.3$
OR (with a little algebra manipulation):

$d = (AB/p) \times 57.3$ (p in degrees)

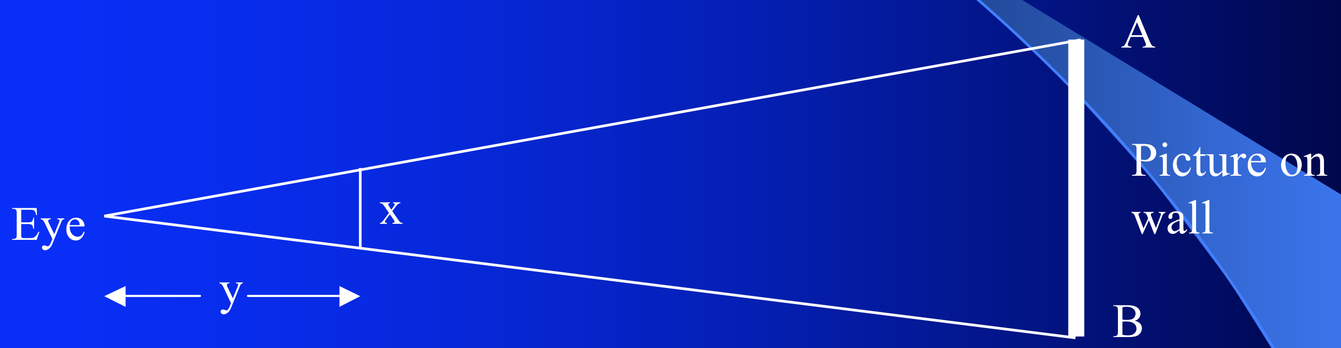
$d = (AB/p) \times 206{,}265$ (p in arcsecs)

Outdoor approximation

- It’s impossible to measure p directly. However, if the distance to the background is >>> d, then angle p’ is approximately equal to p.

- We can measure p’ just as we have measured angular size….by sighting on points C and D with a ruler and a meter stick.

Measuring Angular Size



Hold ruler in front of your eye. Match up "x" with A and B. Measure x. Partner measures y.

Angular size of picture = (X/Y) * 57.3 degrees

Example

- Measure AB = 8.4 meters
- Measure angle p' (angular size of CD) using ruler and meter stick. x = 5 cm, y = 60 cm.
- Calculate p' = x/y * 57.3 degrees = 4.8 deg.
- Calculate d = 8.4/4.8 * 57.3 = 100 meters.

The “Parallax Formula”

The formula:

$$d = (AB/p'') \times 206{,}265$$

works for ALL applications of astronomical parallax, where p” is the parallax angle in arcsecs. d will have the same units as AB.

Example

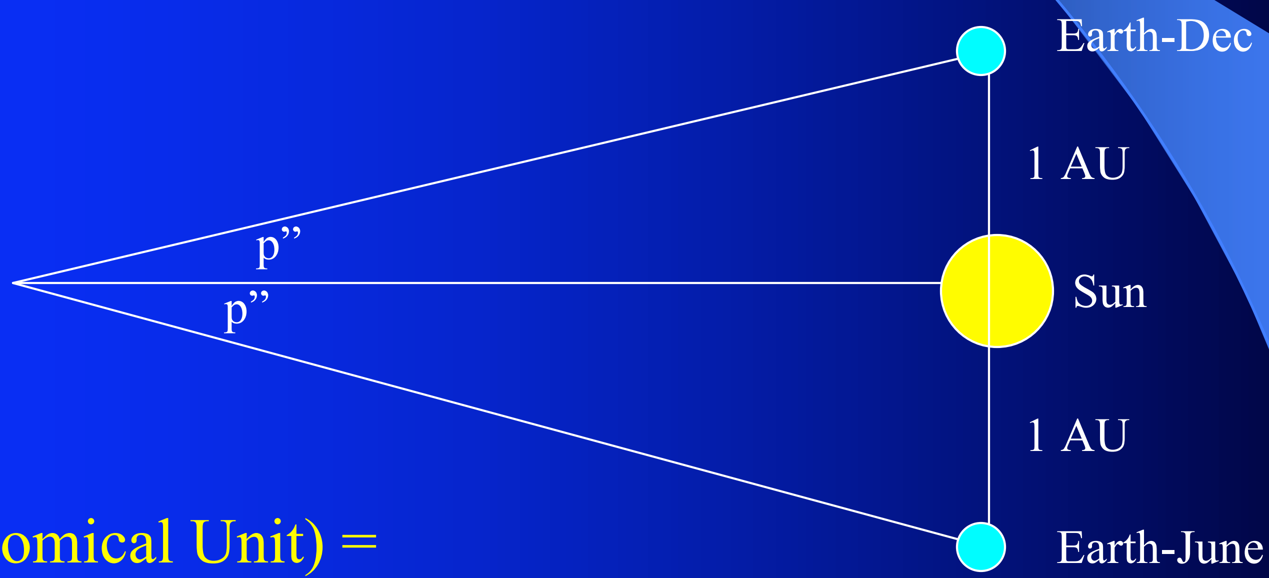
Suppose the Yerkes telescope in Wisconsin and the Leuschner telescope near San Francisco take an image of the same asteroid, at the same time. They measure a parallax angle of 4 arcsecs (4”). The baseline, AB, is the distance between the two scopes = 3200 km.

d = (3200/4) x 206265 km = 165 million km.

(For reference: the Earth-Sun distance is about 150 million km.)

Making the baseline longer:

The “2 AU baseline”



1 AU (Astronomical Unit) =

Earth-Sun distance = 150 million km

Parallax with 2 AU baseline

Plug into the Parallax formula:

$$d = (AB/p'') \times 206{,}265$$
$$d = (2\ AU/2p'') \times 206{,}265$$
$$d = 3.1\ E16/p'' \quad \text{meters}$$

Very large numbers…..need a new unit!!

The Parsec

Definition: the distance that results when an object has a parallax angle of 1 arcsec with a baseline of 1 AU. The word, “parsec”, comes from a combination of “parallax” and “arcsecond”.

So, 1 parsec (pc) = 3.1 E16 meters = 31 trillion km.

Light Year vs. Parsec

One Light Year: the distance light travels in one year = 9.5 E15 meters = 9.5 trillion km.

One parsec = 31 trillion km.

So, one parsec = 3.26 light years

A simple formula

When astronomers observe the parallax of stars using the 2 AU baseline, then the parallax formula becomes:

$$d = 1/p''$$

And d is always in units of parsecs.

Examples: $p'' = 4$ arcsecs, $d = 0.25$ pc.

$p'' = 0.2$ arcsecs, $d = 5$ pc.

Min parallax = Max distance

- The Hipparcos satellite can measure parallax angles to around 1 milliarcsec = 0.001”
- Maximum distance = 1/0.001” =

1000 pc

or about 3300 ly (light years)

How to measure p?

In astronomy we measure the parallax shift directly from two images taken by two different telescopes.

See example of asteroid “Austria” using

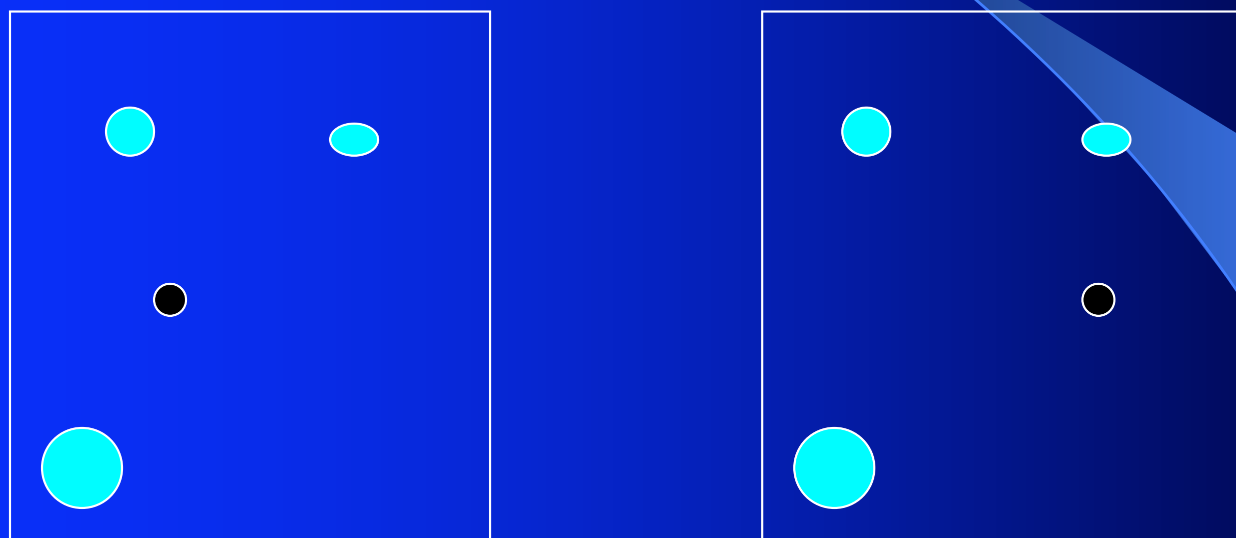
Hands-On Universe-Image Processing

Digital Images

- Each image is made of pixels
- Each pixel represents a certain angle in space
- Given by the **Plate Scale** in “/pixel.

Example

Plate Scale = 0.8”/px.



Measure the shift in pixels. Suppose its 20 pixels.
Then p” = 20 x 0.8 = 16”

Distance calculation

Use the parallax formula:

d = (AB/p”) x 206,265

For p” = 16” and AB = 6,000 km. (e.g.)

d = (6,000/16) x 206,265 = 7.7 E7 km = .77 AU